PERIODIC VARIATIONS IN HUMAN PERFORMANCE

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THESIS

PERIODIC VARIATIONS IN HUMAN PERFORMANCE

by

Francis Leroy Sink

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Periodic Variations in Human Performance

by

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This paper investigates the periodic variation in human performance predicted by Biorhythm theory. Fourier analysis was performed on performance data of three subjects. The results indicated that the postulated basic biorhythmic cycles exist. Comparison of the phase of predominate experimental frequency with the phase predicted by biorhythm indicated that the frequencies may not be as stable as the theory suggests.

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I. INTRODUCTION

A. BACKGROUND

During the late 1800's and early 1900's, researchers reported finding periodic variations in mental, physical, and emotional capabilities of humans. These reported cycles form the basis of biorhythm theory.

The proponents of Biorhythm theory have hypothesized that the mental cycle is 33 days long, the emotional cycle is 28 days long, and the physical cycle is 23 days long. Furthermore they have suggested that these cycles begin on the day of birth and continue throughout life with such precision that an individual can calculate his position with regard to any cycle.

B. BIORHYTHM DISCOVERY

Thommen [1973] has described the work of early biorhythm researchers and the progression from discovery to present. The discovery of each cycle as presented by Thommen is outlined below.

The initial development began about the turn of the century with the work of Dr. Herman Swoboda. His original investigations dealt with and culminated in his postulation of two basic cycles; one 23-day and one 28-day. Swoboda was principally a psychologist and was more interested in investigating whether man's feelings and actions were also influenced by these cyclic phenomena.

Concurrently and independently, Dr. Wilhelm Fliess observed a 23 and 28 day cycle in the outbreak of fevers and deaths. Dr. Fliess had a well founded background in mathematics and statistics. He presented an in depth analysis of his work in a 564 page book entitled <u>The Course of Life</u> [Thommen, 1973].

During the 1920's Dr. Alfred Teltsher, who had a doctorate in engineering, analyzed the performance records of 5,000 high school and college students. From his analysis he concluded that the high and low fluctuations in performance followed a definite 33-day cycle. From 1928 to 1932, Dr. Rexford Hersey and Dr. Michael Bennet conducted a study of emotions of workers in a railroad shop for the Pennsylvania Road. An analysis of this study revealed a cyclic variation in emotions with a period of 33 to 36 days [Thommen, 1973].

From the works of these early researchers the following descriptions of the three biorhythms have been postulated.

It has been hypothesized that the physical cycle is twenty-three days long. The first 11½ days of the cycle are the positive half and the last 11½ days are negative. The days where a transition from positive to negative or negative to positive occurs is termed a critical day. The critical period usually includes 12 hours on either side of the point of transition. Theoretically, during the positive half of the cycle an individual is stronger and is better suited for heavy physical work and athletic contests. During the critical period the individual is more subject to physical

ailments. As such, it has been suggested that during the negative half individuals should avoid over exertion and attempt to use this period for rest. [Willis, 1973].

The emotional cycle is 28-days long with each half cycle 14-days long. During the first half (positive half) individuals tend to be emotionally more stable than the negative half. Maximum instability occurs during the critical period. [Willis, 1973].

The intellectual cycle is 33-days long and is divided into two 16½ day segments. During the first period, the individual is mentally more alert than during the second half. Again the critical day is the period of minimum intellectual stability [Willis, 1973].

C. RECENT RESEARCH

Most recent research in the area of biorhythms has been the correlation of accidents, deaths and illnesses with various phases of the biorhythmic cycles. Three of these studies as reported by Willis [Willis, 1973] are outlined below.

In Japan, the Ohmi Railroad Company records showed that of 331 accidents during the past year 92 or 28% occurred on a critical day of the operator. If these accidents had occurred randomly, we could expect 20.4% to fall on a single, double, or triple critical days. The probability of this occurrence or a more extreme occurrence (greater than 92) is .001 assuming complete random accident occurrences. The Ohmi Railroad has instructed its operators in biorhythm theory and

instituted a procedure that informs the operator of his biorhythmic state. Since adopting this procedure, the Nagahama Service Center has logged over 2,000,000 accident free kilometers. [Willis, 1973]

Analysis of patient records at a medical facility as to deaths, accidents and medical incidents revealed that 50% of the accidents and deaths occurred on a critical day. Six percent of heart attacks and other such medical incidents occurred on a critical day. If these incidents were distributed uniformly, only 20.4% would be expected to occur on critical days. [Willis, 1973]

A survey of 100 single car fatalities in which the driver was killed yielded the contents of Table I. For comparison the expected number in each category assuming complete random occurrences is also shown.

Critical Days	Obs #	Expected #	Ratio Obs/Exp.
PEI	1	.038	26.32
PE	6	.58	10.34
EI	4	.40	10.0
PI	2	.49	4.08
P	16	7.6	2.1
I	10	5.1	1.96
E	8	6.1	1.31

P-Physical, E-Emotional, I-Intellectual

Table I. Observed and Expected Accidents on Critical Days.

D. OBJECTIVES

To date, most research in biorhythms has been in the analysis of field accident data. This type of analysis seeks

to correlate individual accidents to various phases of the biorhythm curve. Since this line of investigation typically uses only one data point per individual, it is difficult to derive quantitative measures of variation within an individual. Another disadvantage to field research of this nature resides in the fact that the analysis of the data usually requires a subjective evaluation as to who or what caused the incident. The present experiment seeks to overcome these disadvantages by measuring a performance parameter of an individual over a long period of time in a controlled laboratory setting. Therefore, the primary objective of this research was to attempt to determine the presence or absence of periodic fluctuations in performance on a laboratory task as biorhythm theory suggests. Secondly, if a periodic fluctuation was observed, to attempt to determine the periods and amplitudes of such fluctuations.

II. EXPERIMENTAL METHOD

A. EQUIPMENT

The equipment consisted of a panel upon which the digits 1 through 8 could be displayed and 8 response buttons. Each response button was related to one and only one of the digits 1 through 8. This relationship was kept constant throughout the experiment. The ordering of the buttons was such that row one corresponded to the digits 1 through 4 in ascending order from left to right. Row two corresponded to the digits 5 through 8 in ascending order left to right. The physical relationship of the stimulus panel and response buttons is shown in Figure 1.

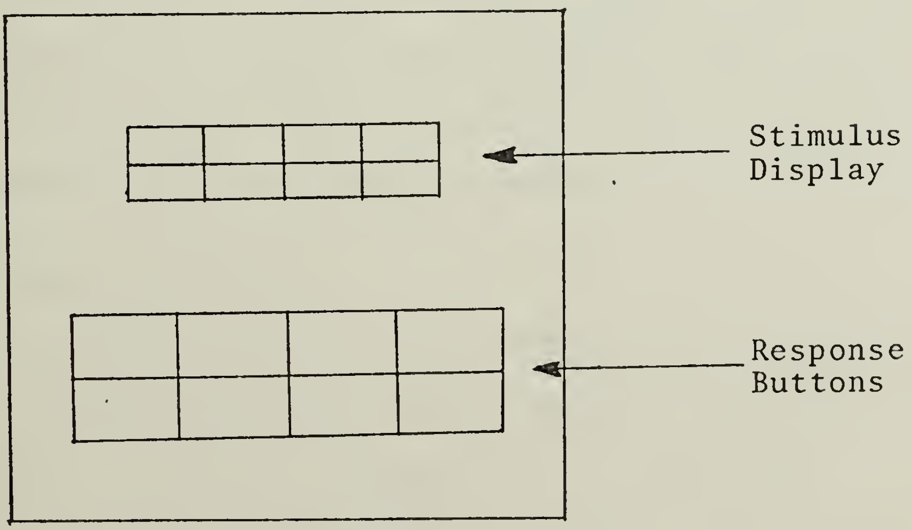

Figure 1.

B. SUBJECTS

Three unpaid volunteer subjects were utilized in the present experiment. All were male officer students at the Naval Postgraduate School. Subject one was 36 years old, subject two was 35, and subject three was 30. During the course of the experiment, the subjects were not given any biorhythmic data.

C. TASK

The experimental task required the subject to respond as quickly as possible to the displayed stimuli. The response required was depressing the button corresponding to the displayed digit. Only one response was allowed for any one stimuli. The stimulus digits were displayed at a rate of one per second. The ordering of the digits was random as determined by a random number table. This ordering was changed daily and the ordering was not known by the subject. Each day, before data collection began, each subject was allowed a ten second warm up period.

D. DATA COLLECTION

The data collection was conducted at the same time each day in order to nullify any circadian variations. The collection of data was carried out in three phases. During phase one, only the digits one and two were presented in a random sequence. This phase continued until five response times were recorded. During the second phase, the digits one through four were displayed in a random order. This was

continued until five response times were recorded. During phase three, the digits one through eight were displayed in a random order and five response times were recorded. Before the beginning of each phase, the subject was informed as to which digits would be displayed and that each digit was equally likely to appear during each display period.

III. DATA ANALYSIS

A. COMPUTING MOVEMENT TIME AND INFORMATION PROCESSING RATE

Experiments carried out by Fitts, Peterson and Wolpe [1963] provided evidence which suggests that reaction time is a function of the probabilities of the stimuli. (i.e., The more likely an event is to occur, less is the time required to react to it.) The functional form they observed was

(1) $RT = a + bH$

where

$RT \equiv$ reaction time

$H \equiv$ uncertainty associated with the stimuli (bits of information)

$b \equiv$ seconds/bit of information processed

$1/b \equiv$ information processing rate (bits per second)

$a \equiv$ movement time.

H is a term developed in communication theory by Shannon and Weaver [1949]. From their work,

(2) $H \equiv -\sum_{i=1}^{n} P(i) \log_2 p(i)$ bits/element.

$P(i) \equiv$ probability of the i^{th} stimuli occurring.

For n equally likely stimuli (eg(2)) becomes

(3) $H = \log_2 n.$

For present work, three tasks were administered sequentially with five repetitions of each task. The task involved

making a known response to an uncertain stimuli. The first task utilized two equally likely stimuli (one bit), the second utilized four equally likely stimuli (two bits) and the third used eight equally likely stimuli (three bits).

The fifteen reaction times were then used in a linear regression model to produce a least square error estimate of a and b. The equations used were:

$$(4) \qquad b \doteq \frac{N \sum_{i=1}^{15} X_i Y_i - \sum_{i=1}^{15} X_i \sum_{i=1}^{15} Y_i}{N \sum_{i=1}^{15} (X_i)^2 - (\sum_{i=1}^{15} X_i)^2}$$

where

$X_i \equiv$ bits of information

$Y_i \equiv$ reaction time; $0 < i \leq 5$ for one bit, $6 \leq i \leq 10$ for two bit, $11 \leq i$ for three bit

$$X_i = \begin{cases} 1 & 0 < i \leq 5 \\ 2 & 6 \leq i \leq 10 \\ 3 & 10 < i \leq 15 \end{cases}$$

$N \equiv$ total number of data points.

$$(5) \qquad a = \frac{\sum_{i=1}^{15} Y_i}{15} - b \frac{\sum_{i=1}^{15} X_i}{15}$$

B. DETERMINING SIGNIFICANT VARIATION

At the conclusion of the data collection phase, data for each subject consisted of three sets of measurements. Set one was the average reaction time. Each point in this set was the average of the fifteen reaction times recorded during

a daily session. The distributional form for the two bit reaction time was found to be approximately Normal (μ,σ^2). The assumption was made that on any day the distribution of the one bit decision was Normal $(\mu - c,\sigma^2)$ and the distribution of the three bit decision was Normal $(\mu + c,\sigma^2)$ where c is a constant. The constant c was estimated as the inverse of the information processing rate. The constant c was added to the one bit data and subtracted from the three bit data to yield fifteen data points which were distributed Normal (μ,σ^2). The variance was estimated using the unbiased estimator,

$$\sigma^2 = \frac{1}{n-1} \sum_{n=1}^{15} (\overline{x} - x_n)^2,$$

where

$\overline{x} \equiv$ mean

$n \equiv$ number of data points

$x_n \equiv$ value of n^{th} data point.

The mean of the distribution was estimated by

$$\overline{x} = \frac{1}{n} \sum_{n=1}^{15} x_n .$$

With the estimated value of σ^2, the confidence interval for $\alpha = .05$ was calculated using the Student t distribution. The relation used was $L = 2\, t_{n-1}\, (1-\alpha/2)(S^2/n)$, where

$n - 1 \equiv$ degrees of freedom

$n \equiv$ number of data points

$(1-\alpha/2) \equiv$ argument for t distribution.

This yielded the following confidence intervals centered around $\bar{x}$.

Subject one: $L = .036$.

Subject two: $L = .052$.

Subject three: $L = .044$.

The grand mean (X_G) for each subject was computed and the data was analyzed to see if any data points lie outside the interval $X_G = \pm L/2$. In all cases this was found to be so, indicating a significant variation in daily performance. This lead to the Fourier Analysis of the data set described in the next section. It was also decided to conduct a Fourier Analysis of the movement time (MT) data and the information processing rate (IPR) data.

C. FREQUENCY ANALYSIS OF DATA

In order to determine periodicity within the data set it was decided to use a Fast Fourier Transform (FFT). Since this operation required equal interval data, this necessitated generating data points for days when subjects were not available. This was done by a linear interpolation between the point immediately preceding and the point immediately following the interval with no data. This procedure was necessary for all weekend days and holidays. Although the exact effect of the addition of data is not known, it was felt that most effects would be restricted to frequencies with periods of 5 to 7 days. The FFT indicated periodicities within each data set. On this basis, the function described

by the data set was approximated by a Fourier Series of the form:

$$Y(NN) = \frac{a_o}{2} + \sum_{n=1}^{35} \left(a_n \cos \frac{\Pi(NN)P}{N} + b_n \sin \frac{\Pi(NN)P}{N}\right),$$

where

$N \equiv \frac{1}{2}$ (number of data points)

$NN \equiv 0,1,2, \cdots ,2N-1$ (days)

$P \equiv$ harmonic number

$Y(NN) \equiv$ value of function on day NN.

An existing subroutine from the Naval Postgraduate School computer library was used to compute the coefficients a_n and b_n. The subroutine is attached as Appendix M. The root mean square value of a_n and b_n was computed to give the amplitude of n^{th} harmonic. In order to get a better approximation of the frequency envelope at the lower frequencies, the data set was reduced in increments of one data point until the final data set had only 46 points. This operation is valid under the assumption that the amplitude of the various frequency components do not change over time. The frequency envelopes of reaction time, movement time, and information processing rate are shown in Figures 2 through 10.

The phase of each harmonic can be found by using the following relation:

$$\theta = \arctan \frac{a_n}{b_n},$$

where a_n and b_n are the Fourier Coefficients.

Subject One

Reaction Time Frequency Envelope

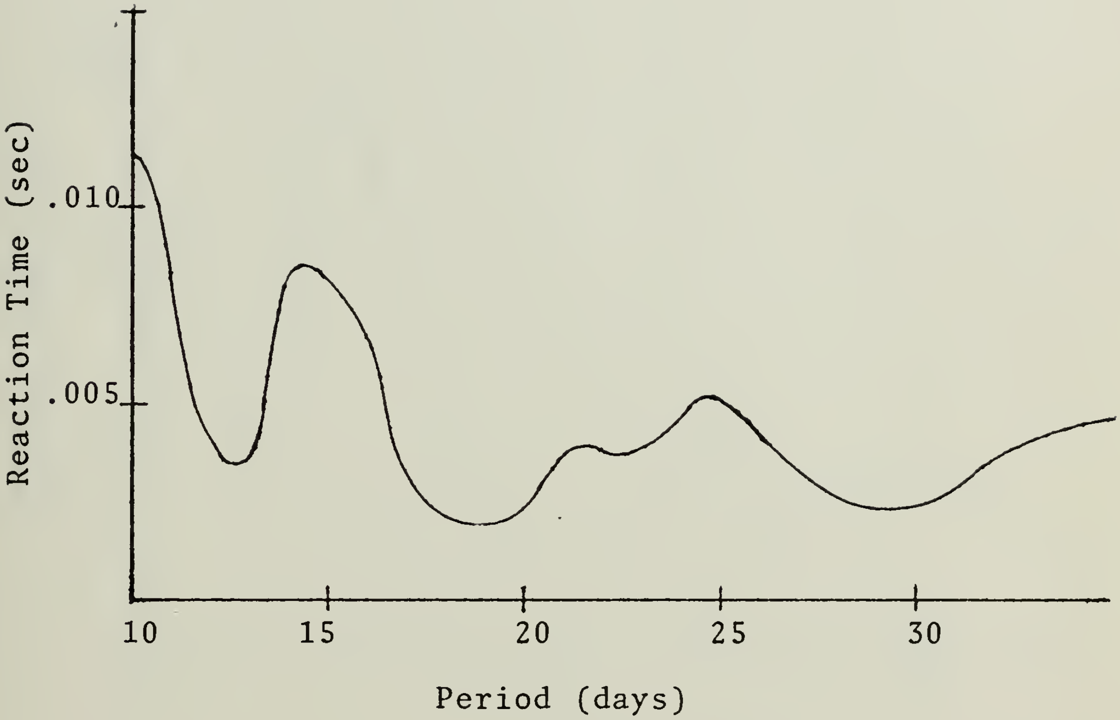

Figure 2.

Subject Two

Reaction Time Frequency Envelopes

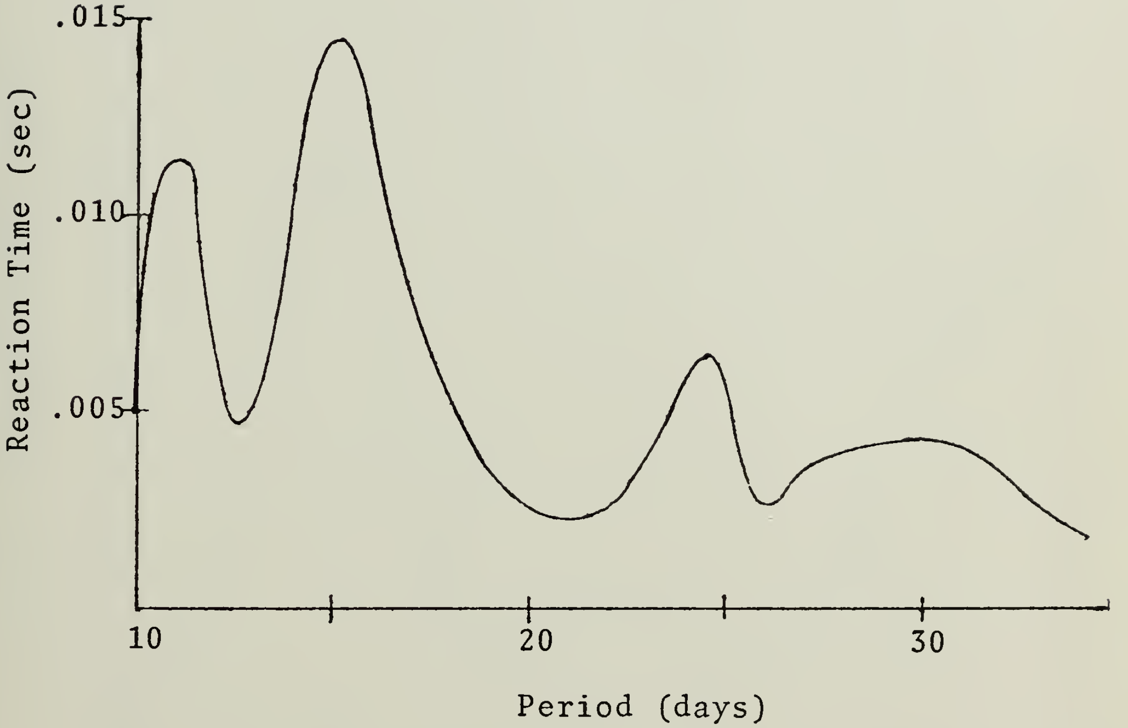

Figure 3.

Subject Three

Reaction Time Frequency Envelope

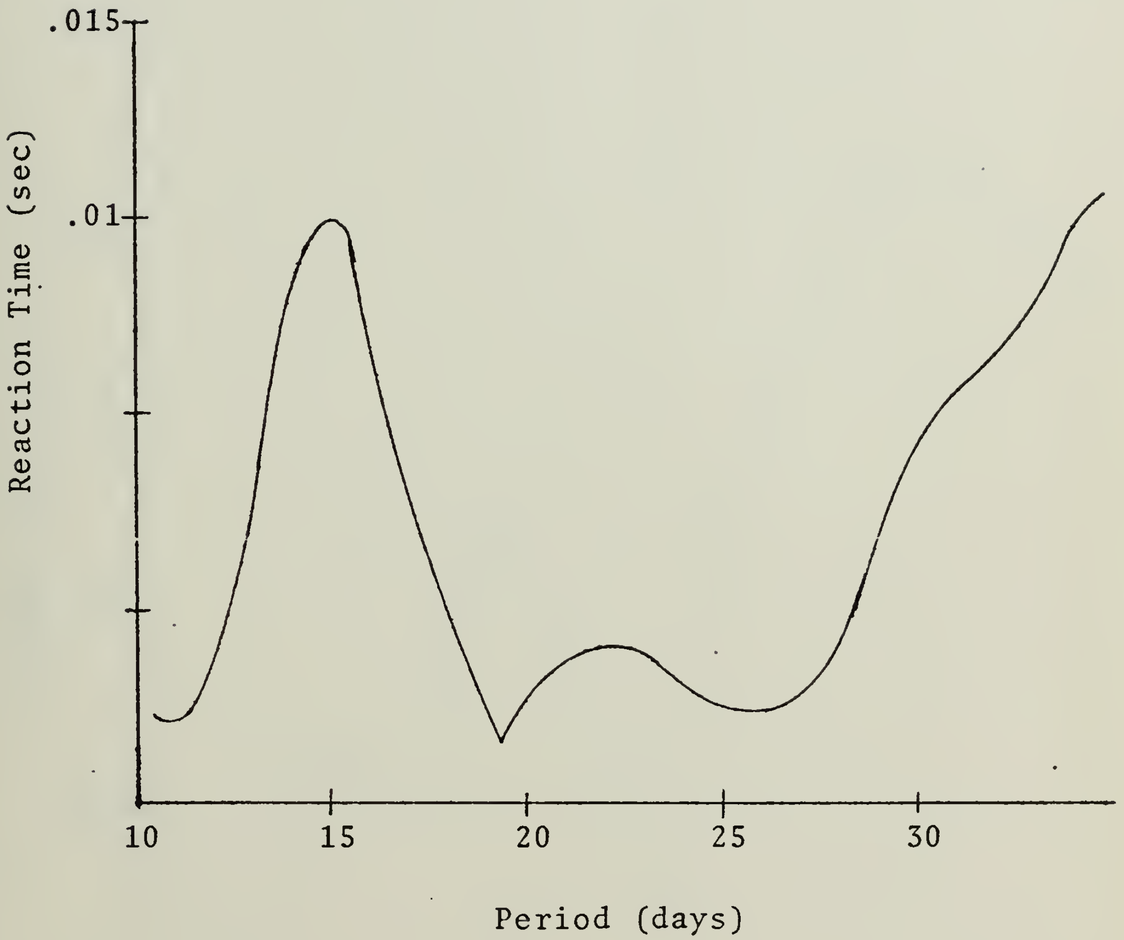

Figure 4.

Subject One

Movement Time Frequency Envelope

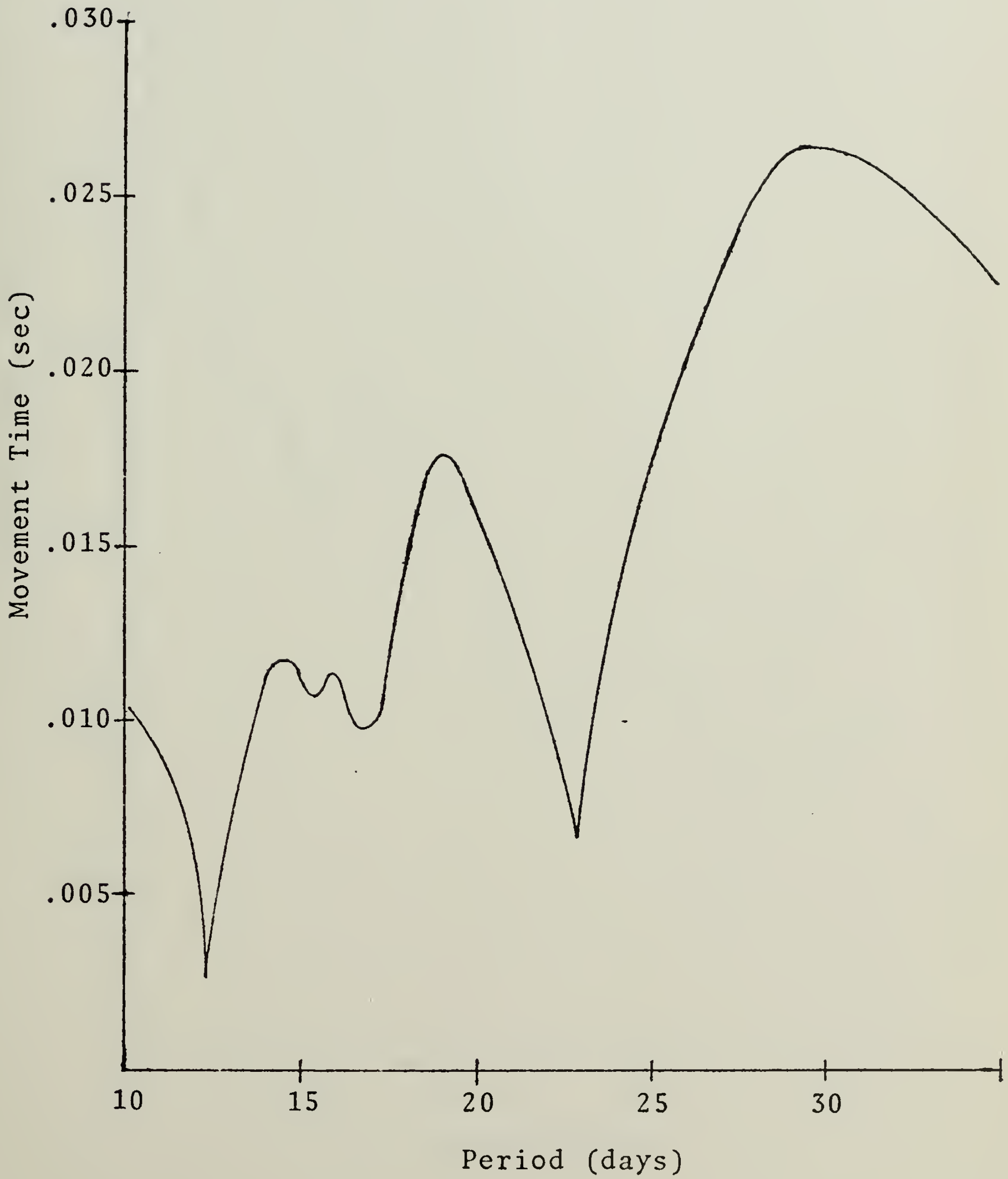

Figure 5.

Subject Two

Movement Time Frequency Envelope

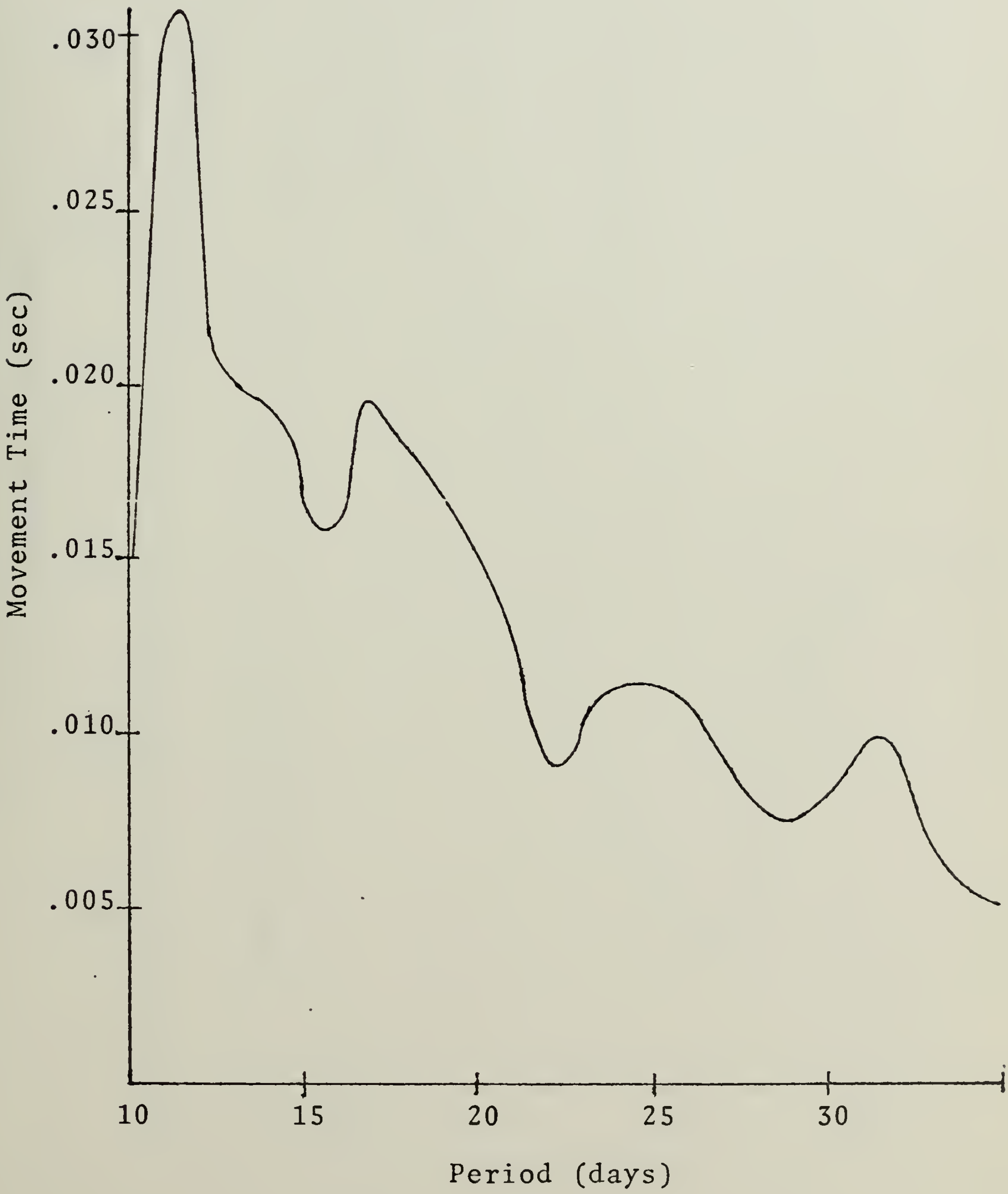

Figure 6.

Subject Three

Movement Time Frequency Envelope

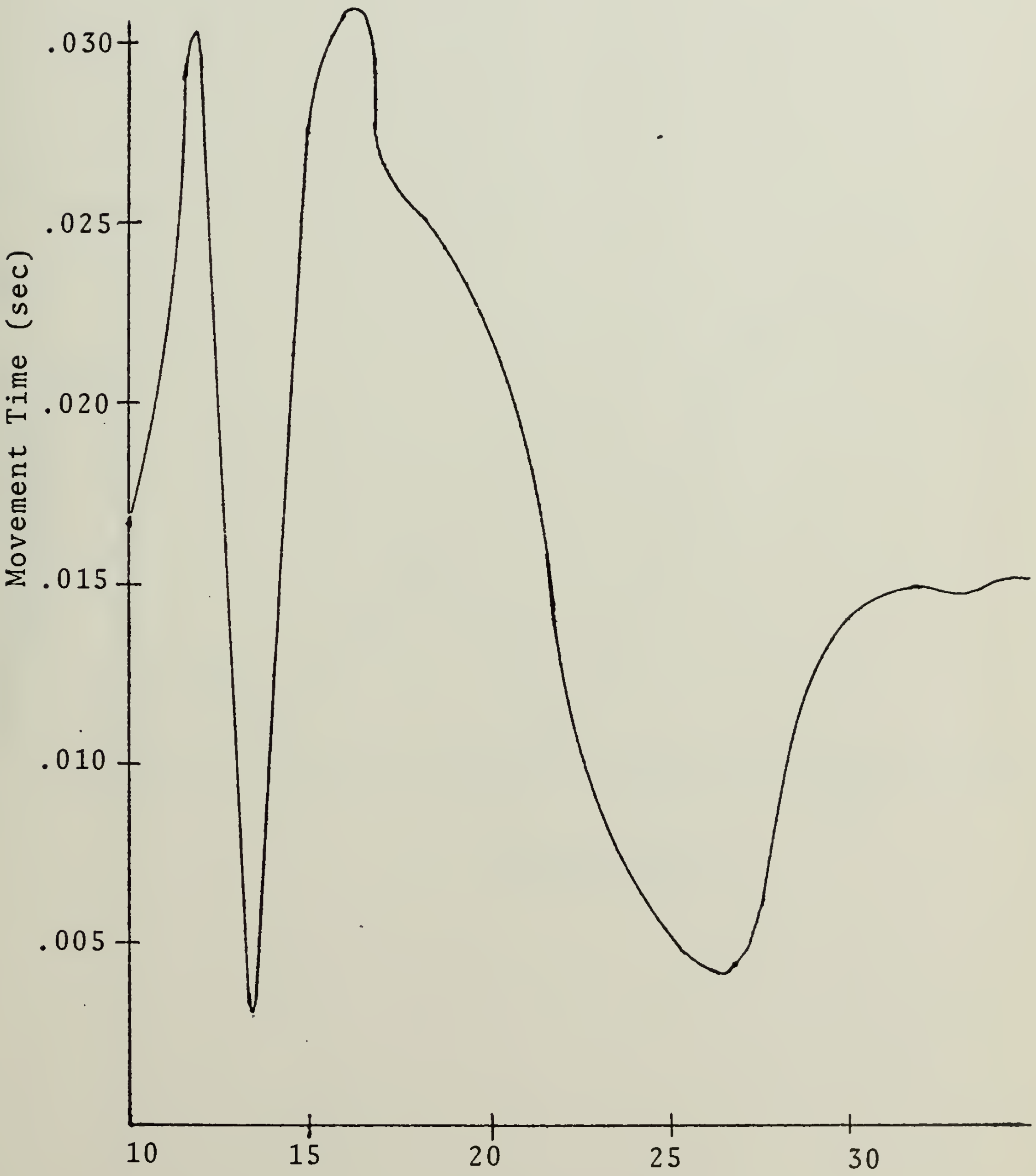

Figure 7.

Subject One

Information Processing Rate Frequency Envelope

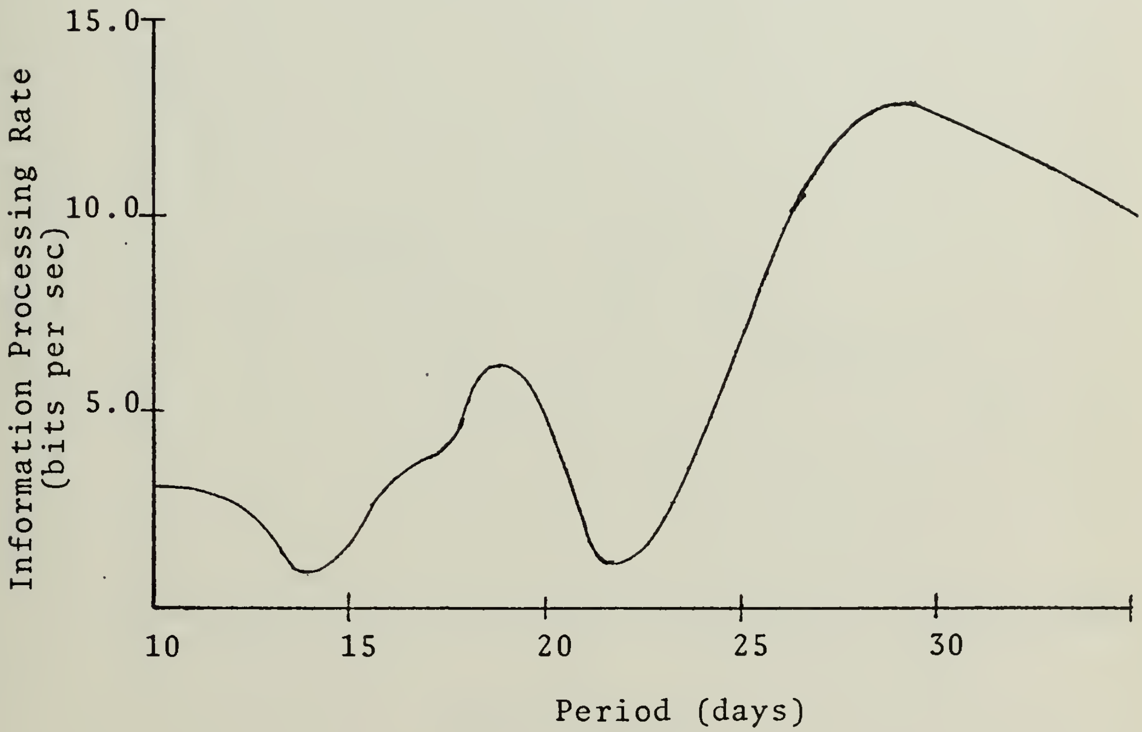

Figure 8.

Subject Two

Information Processing Rate Frequency Envelope

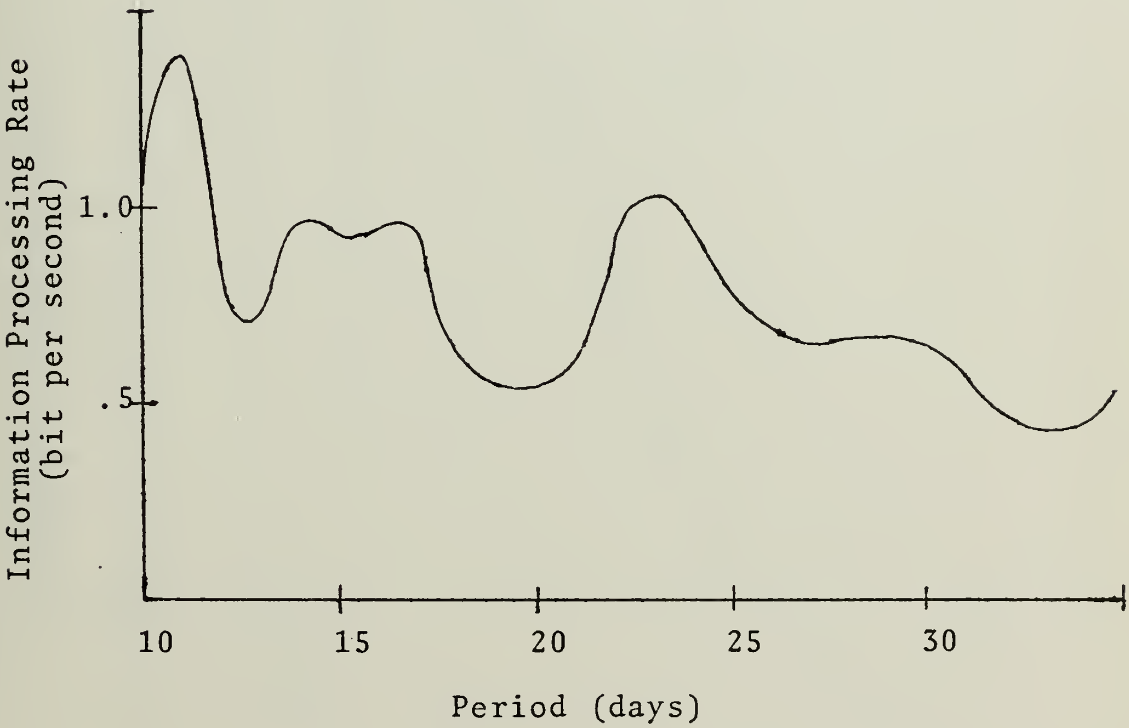

Figure 9.

Subject Three

Information Processing Rage Frequency Envelope

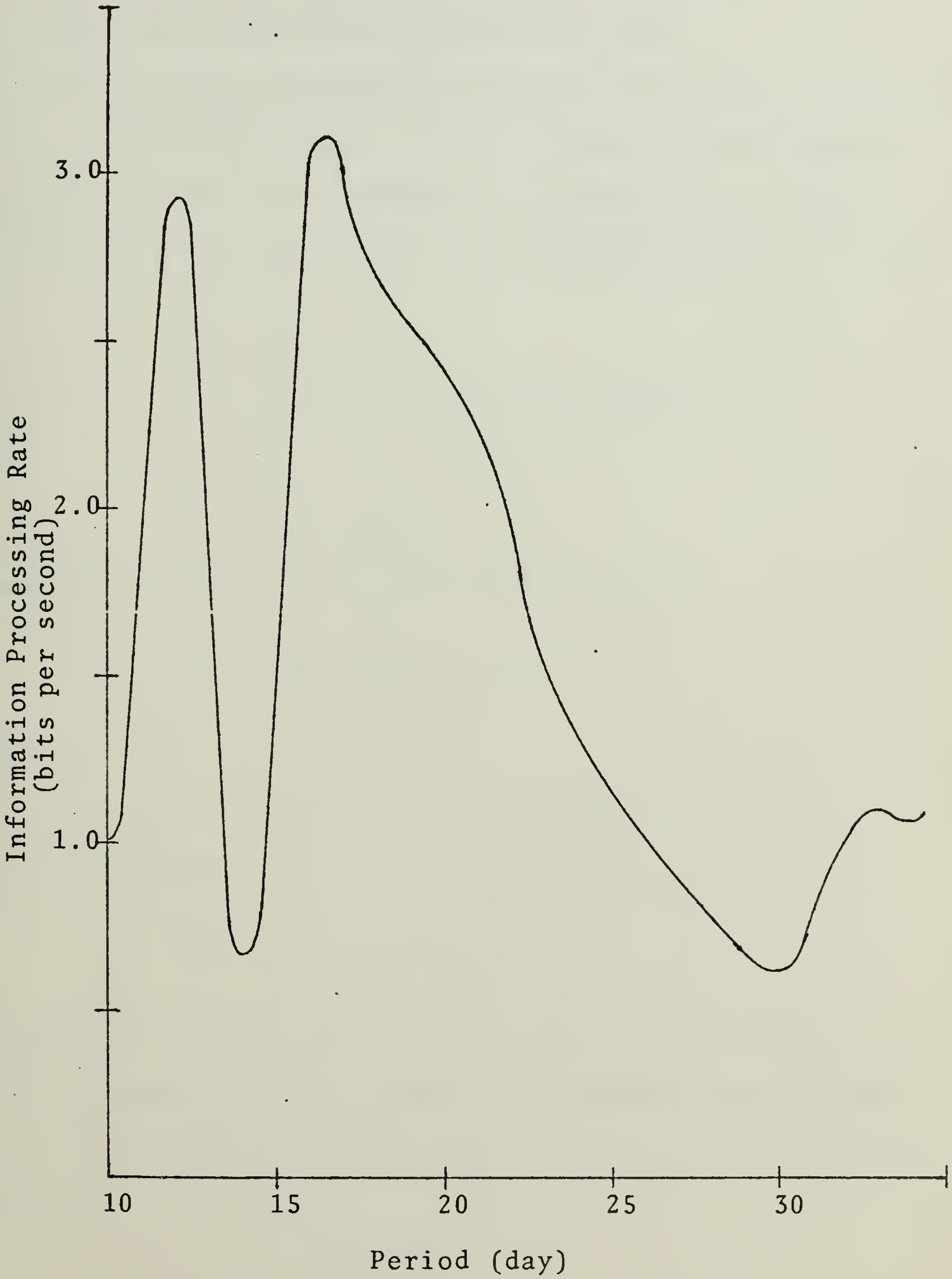

Figure 10.

The phase angle θ for periods with significant amplitudes are shown in Table II.

D. LEVEL OF SIGNIFICANCE IN FREQUENCY DATA

Under the Null Hypothesis, that is that f(t) is a Gaussian Process, the coefficients of the sine and cosine functions in the Fourier series are assumed to be independent, identically distributed Normal with mean of 0 and variance of σ^2. Since

$$A_n^2 = a_n^2 + b_n^2$$

$$A_n \equiv \text{amplitude of } n^{th} \text{ harmonic}$$

then

$$A_n^2 \sim \exp\left(\frac{1}{2\sigma^2}\right).$$

σ^2 can be estimated by the unbiased estimator

$$S^2 = \frac{1}{N-1} \sum_{n=1}^{N} (\mu - a_n)^2,$$

where

$$N = \text{number of observations of } a_n.$$

Since μ is assumed to be zero, this reduces to

$$S^2 = \frac{1}{N-1} \sum_{n=1}^{N} (a_n)^2.$$

The values of the S^2 computed are shown in Table II.

The probability (α) an amplitude greater than or equal to A_n would arise from a Gaussian Process is found from the relation

$$\alpha = e^{-A_n^2/2S^2}.$$

In the original set of 70 points, there are 6 harmonics that could be significant in the range of 10 - 35 days. The confidence level that can be associated with the amplitude of one of these harmonics is:

$$\alpha = 1 - (1 - e^{-A_n^2/2S^2})^6 .$$

These values of α for the peaks in the frequency envelopes are shown in Table II.

IV. RESULTS AND CONCLUSIONS

Table II gives the data derived for the most obvious peaks in the various frequency envelopes. Of the 14 periods with amplitudes significant at the .1 level, nine are within one day of half of one of the three biorhythm cycles. The probability of this occurrence or a more extreme occurrence is .015, assuming a uniform distribution of significant amplitudes.

The significance of periods with one half the biorhythmic periods can be seen by examining the critical - non critical day cycle. There are two critical days within each period. Hence, the period of a critical day - non critical day cycle is one half the biorhythmic period.

Although all subjects have significant periods within one day of 11.5, 14, and 16.5, an examination of the phases associated with each indicated that the periodic phenomena apparently arise from different sources. Since all subjects performed the same task each day, it can be assumed that the cyclic phenomena was not induced by the experiment.

During the analysis of the data, it was found that two unknown effects were present. The first was the interpolation of missing data points. This effect can be eliminated by insuring continuous availability of subjects. The other effect was the individual's environment. Outside of the test situation, each individual had a unique environment which may have affected his performance. It is suggested

that in further investigations an attempt be made to obtain subjects with a uniform environment during the course of the experiment.

An experiment involving a similar procedure but with subjects drawn from a population where extraneous influences can be controlled (e.g. prisons, Naval Academy) may promote obtaining information regarding the true influence of biorhythms. Also a larger population of subjects would allow estimates to be made of the variation in the influence of biorhythms in the general population.

Table II

Function	S^2	Period (days)	Amplitude	α	Phase	Critical-Non Critical Cycle Phase
				SUBJECT ONE		
IPR	8.55	29	12.8	.0007	357°	P - 125°
IPR	3.55	19	6.68	.42	155°	E - 334°
MT	33.8×10^{-6}	19	.0175	.074	131°	I - 272°
MT	33.8×10^{-6}	30	.0265	.0007	175°	
RT	13.3×10^{-6}	10	.0113	.061	177°	
RT	13.3×10^{-6}	14.5	.0085	.384	325°	
				SUBJECT TWO		
IPR	.1755	11	1.43	.027	160°	P - 125°
IPR	.1755	23	1.03	.297	144°	E - 180°
IPR	.1755	14	.98	.375	270°	I - 109°
IPR	.1755	16.5	.98	.375	52°	
MT	81.6×10^{-6}	16.7	.0195	.518	116°	
MT	81.6×10^{-6}	11.5	.0307	.021	3°	
RT	11.7×10^{-6}	11.0	.0115	.020	91°	
RT	11.7×10^{-6}	15.0	.0137	.0013	150°	
				SUBJECT THREE		
IPR	.634	11.5	2.94	.007	67°	P - 266°
IPR	.634	16	3.12	.003	178°	E - 231°
MT	55.9×10^{-6}	11.8	.0304	.0013	58°	I - 65°
MT	55.9×10^{-6}	16.25	.0312	.001	145°	
RT	16.4×10^{-6}	14.8	.0149	.007	16°	
RT	16.4×10^{-6}	35	.0158	.003	328°	

APPENDIX A

Computation of probability of a critical day assuming independence and uniform distribution of critical days.

1. Since two critical days occur during each cycle, if a large number (N) of people are sampled on any given day, there should be (2/23)(N) in a critical physical day; (2/28)(N) in a critical emotional day; and (2/33)(N) in a critical mental day.

In terms of probabilities:

P_p = .087 (probability of a physical critical day)

P_e = .071 (probability of an emotional critical day)

P_m = .061 (probability of an intellectual critical day).

2. Computing the number of single critical days.

(a) Physical $= (P_p)(1-P_e)(1-P_m) = .076$

(b) Emotional $= (P_e)(1-P_p)(1-P_m) = .061$

(c) Mental $= P_m(1-P_p)(1-P_e) = .051.$

Total probability of single critical day = .188.

3. Computing the number of double critical days.

(a) P & E $= (P_p)(P_e)(1-P_m) = .0058$

(b) P & M $= (P_p)(P_m)(1-P_e) = .0049$

(c) M & E $= (P_m)(P_e)(1-P_p) = .0040.$

Total probability of double critical day = .0147.

4. Computing the probability of a triple critical day

$P_{triple} = (P_e)(P_m)(P_p) = .00038.$

5. Total probability of having a critical day (single, double, or triple)

$$P_{single} + P_{double} + P_{triple} = .2031.$$

APPENDIX B

SUBJECT ONE

Date	Average Reaction Time	Date	Average Reaction Time
4-30	.383	6-4	.325
5-1	.407	6-5	.346
5-2	.361	6-6	.348
5-3	.367*	6-7	.348
5-4	.373*	6-8	.342*
5-5	.379*	6-9	.337*
5-6	.385	6-10	.332
5-7	.366	6-11	.359
5-8	.397	6-12	.387
5-9	.385	6-13	.354
5-10	.391	6-14	.323
5-11	.377*	6-15	.318*
5-12	.363*	6-16	.348*
5-13	.350	6-17	.378
5-14	.367	6-18	.407
5-15	.374	6-19	.358
5-16	.373	6-20	.361
5-17	.375	6-21	.360
5-18	.375*	6-22	.363*
5-19	.375*	6-23	.264* .301
5-20	.375	6-24	.365
5-21	.384	6-25	.399
5-22	.375	6-26	.349
5-23	.339	6-27	.350*
5-24	.341*	6-28	.351
5-25	.343*	6-29	.353*
5-26	.345*	6-30	.355*
5-27	.347*	7-1	.357
5-28	.350	7-2	.365
5-29	.370	7-3	.364
5-30	.358	7-4	.362*
5-31	.371	7-5	.359*
6-1	.363*	7-6	.357*
6-2	.355*	7-7	.354*
6-3	.348	7-8	.352

*Interpolated Data Points

APPENDIX C

SUBJECT ONE

Date	Movement Time	Date	Movement Time
4-30	.298	6-4	.269
5-1	.327	6-5	.321
5-2	.273	6-6	.289
5-3	.263*	6-7	.255
5-4	.255*	6-8	.254*
5-5	.245*	6-9	.253*
5-6	.238	6-10	.252
5-7	.199	6-11	.305
5-8	.168	6-12	.351
5-9	.228	6-13	.301
5-10	.294	6-14	.253
5-11	.285*	6-15	.275*
5-12	.280*	6-16	.297*
5-13	.273	6-17	.318
5-14	.320	6-18	.263
5-15	.291	6-19	.350
5-16	.268	6-20	.276
5-17	.335	6-21	.323
5-18	.320*	6-22	.347*
5-19	.305*	6-23	.350*
5-20	.293	6-24	.364
5-21	.319	6-25	.306
5-22	.345	6-26	.296
5-23	.281	6-27	.293*
5-24	.286*	6-28	.289
5-25	.289*	6-29	.295*
5-26	.292*	6-30	.302*
5-27	.294*	7-1	.306
5-28	.296	7-2	.301
5-29	.297	7-3	.249
5-30	.252	7-4	.252*
5-31	.322	7-5	.257*
6-1	.300*	7-6	.262*
6-2	.280*	7-7	.267*
6-3	.261	7-8	.272

*Interpolated Data Points

APPENDIX D

SUBJECT ONE

Date	Information Processing Rate	Date	Information Processing Rate
4-30	23.58	6-4	35.7
5-1	25.00	6-5	78.13
5-2	22.7	6-6	33.78
5-3	20.42*	6-7	21.55
5-4	18.14*	6-8	22.7*
5-5	15.86*	6-9	23.85*
5-6	13.58	6-10	25.0
5-7	12.02	6-11	36.8
5-8	8.74	6-12	56.82
5-9	12.76	6-13	37.88
5-10	20.5	6-14	28.41
5-11	22.35*	6-15	45.60*
5-12	24.6*	6-16	69.81*
5-13	26.04	6-17	80.0
5-14	43.1	6-18	13.89
5-15	24.04	6-19	80.0
5-16	18.94	6-20	23.6
5-17	50.0	6-21	54.35
5-18	41.49*	6-22	62.9*
5-19	33.0*	6-23	71.45*
5-20	24.51	6-24	80.0
5-21	31.25	6-25	21.55
5-22	65.79	6-26	37.88
5-23	34.72	6-27	34.97*
5-24	35.12*	6-28	32.05
5-25	35.53*	6-29	34.39*
5-26	35.94*	6-30	36.73*
5-27	36.34*	7-1	39.06
5-28	36.76	7-2	31.25
5-29	27.17	7-3	17.36
5-30	18.94	7-4	18.89*
5-31	40.32	7-5	20.42*
6-1	34.45*	7-6	21.94*
6-2	28.59*	7-7	23.47*
6-3	22.73	7-8	25.0

*Interpolated Data Points

APPENDIX E

SUBJECT TWO

Date	One Reaction Time	Date	One Reaction Time
4-30	.513	6-4	.417
5-1	.425	6-5	.425
5-2	.421	6-6	.421
5-3	.413	6-7	.419
5-4	.414*	6-8	.416*
5-5	.416*	6-9	.413*
5-6	.417	6-10	.410
5-7	.413	6-11	.449
5-8	.438	6-12	.473
5-9	.446	6-13	.474
5-10	.455	6-14	.464
5-11	.438*	6-15	.446*
5-12	.421*	6-16	.429*
5-13	.404	6-17	.412
5-14	.426	6-18	.403*
5-15	.438	6-19	.395
5-16	.434	6-20	.412
5-17	.405	6-21	.467
5-18	.412*	6-22	.459*
5-19	.419*	6-23	.452*
5-20	.426	6-24	.444*
5-21	.425	6-25	.437
5-22	.398	6-26	.443
5-23	.429	6-27	.446
5-24	.447	6-28	.441*
5-25	.443*	6-29	.436*
5-26	.438*	6-30	.432*
5-27	.433*	7-1	.427*
5-28	.428	7-2	.423
5-29	.447	7-3	.418
5-30	.421	7-4	.414*
5-31	.439	7-5	.411*
6-1	.432*	7-6	.408*
6-2	.426*	7-7	.405*
6-3	.420	7-8	.402

*Interpolated Data Points

APPENDIX F

SUBJECT TWO

Date	Movement Time	Date	Movement Time
4-30	.383	6-4	.191
5-1	.210	6-5	.175
5-2	.279	6-6	.237
5-3	.186	6-7	.144
5-4	.170*	6-8	.170*
5-5	.155*	6-9	.200*
5-6	.140	6-10	.229
5-7	.257	6-11	.193
5-8	.297	6-12	.249
5-9	.337	6-13	.199
5-10	.167	6-14	.285
5-11	.177*	6-15	.225*
5-12	.190*	6-16	.182*
5-13	.199	6-17	.195
5-14	.278	6-18	.215*
5-15	.281	6-19	.243
5-16	.182	6-20	.189
5-17	.243	6-21	.275
5-18	.260*	6-22	.266*
5-19	.275*	6-23	.250*
5-20	.291	6-24	.247*
5-21	.308	6-25	.223
5-22	.246	6-26	.247
5-23	.215	6-27	.206
5-24	.175	6-28	.210*
5-25	.178*	6-29	.214*
5-26	.180*	6-30	.218*
5-27	.183*	7-1	.222*
5-28	.186	7-2	.277
5-29	.237	7-3	.281
5-30	.222	7-4	.265*
5-31	.237	7-5	.251*
6-1	.235*	7-6	.237*
6-2	.234*	7-7	.222*
6-3	.233	7-8	.208

*Interpolated Data Points

APPENDIX G

SUBJECT TWO

Date	Information Processing Rate	Date	Information Processing Rate
4-30	15.4	6-4	8.87
5-1	9.33	6-5	8.01
5-2	14.04	6-6	10.87
5-3	8.8	6-7	7.27
5-4	8.27*	6-8	8.53*
5-5	7.75*	6-9	9.79*
5-6	7.23	6-10	11.06
5-7	12.76	6-11	7.81
5-8	13.30	6-12	8.93
5-9	18.38	6-13	7.27
5-10	6.94	6-14	11.16
5-11	7.88*	6-15	10.27*
5-12	8.82*	6-16	9.39*
5-13	9.76	6-17	8.5
5-14	13.59	6-18	10.83*
5-15	12.75	6-19	13.16
5-16	7.96	6-20	9.0
5-17	12.38	6-21	10.42
5-18	13.21*	6-22	10.14*
5-19	14.05*	6-23	9.87*
5-20	14.88	6-24	9.60*
5-21	17.12	6-25	9.33
5-22	13.16	6-26	10.25
5-23	9.33	6-27	8.33
5-24	7.35	6-28	9.41*
5-25	7.73*	6-29	10.49*
5-26	8.11*	6-30	11.57*
5-27	8.49*	7-1	12.65*
5-28	8.86	7-2	13.74
5-29	9.54	7-3	14.71
5-30	10.08	7-4	13.82*
5-31	9.92	7-5	12.95*
6-1	10.17*	7-6	12.08*
6-2	10.43*	7-7	11.21*
6-3	10.68	7-8	10.33

*Interpolated Data Points

APPENDIX H

SUBJECT THREE

Date	Average Reaction Time	Date	Average Reaction Time
4-30	.444	6-4	.353
5-1	.365	6-5	.346
5-2	.380	6-6	.337
5-3	.387*	6-7	.339*
5-4	.394*	6-8	.341*
5-5	.401*	6-9	.344*
5-6	.408	6-10	.346
5-7	.392	6-11	.353
5-8	.385	6-12	.371
5-9	.413	6-13	.380
5-10	.352	6-14	.379*
5-11	.373*	6-15	.379*
5-12	.394*	6-16	.378*
5-13	.417	6-17	.377
5-14	.394	6-18	.367
5-15	.399	6-19	.355
5-16	.375	6-20	.361
5-17	.421	6-21	.377
5-18	.412*	6-22	.370*
5-19	.404*	6-23	.363*
5-20	.396	6-24	.356*
5-21	.371	6-25	.350
5-22	.384	6-26	.343*
5-23	.339	6-27	.336
5-24	.343*	6-28	.358
5-25	.347*	6-29	.358*
5-26	.351*	6-30	.357*
5-27	.355*	7-1	.357
5-28	.359	7-2	.354*
5-29	.364	7-3	.352
5-30	.363	7-4	.347
5-31	.357	7-5	.343*
6-1	.364*	7-6	.339*
6-2	.371*	7-7	.334*
6-3	.377	7-8	.329

*Interpolated Data Points

APPENDIX I

SUBJECT THREE

Date	Movement Time	Date	Movement Time
4-30	.341	6-4	.229
5-1	.229	6-5	.210
5-2	.263	6-6	.215
5-3	.259*	6-7	.214*
5-4	.245*	6-8	.213*
5-5	.235*	6-9	.212*
5-6	.227	6-10	.211
5-7	.156	6-11	.250
5-8	.236	6-12	.272
5-9	.294	6-13	.245
5-10	.278	6-14	.255*
5-11	.287*	6-15	.265*
5-12	.298*	6-16	.275*
5-13	.309	6-17	.287
5-14	.298	6-18	.252
5-15	.287	6-19	.255
5-16	.246	6-20	.221
5-17	.188	6-21	.124
5-18	.197*	6-22	.135*
5-19	.209*	6-23	.150*
5-20	.220	6-24	.165*
5-21	.206	6-25	.180*
5-22	.315	6-26	.190*
5-23	.229	6-27	.203
5-24	.240*	6-28	.205
5-25	.252*	6-29	.215*
5-26	.263*	6-30	.225*
5-27	.275*	7-1	.236
5-28	.289	7-2	.233
5-29	.251	7-3	.231
5-30	.244	7-4	.151
5-31	.246	7-5	.160*
6-1	.242*	7-6	.168*
6-2	.235*	7-7	.175*
6-3	.229	7-8	.183

*Interpolated Data Points

APPENDIX J

SUBJECT THREE

Date	Information Processing Rate	Date	Information Processing Rate
4-30	27.17	6-4	16.23
5-1	14.7	6-5	14.7
5-2	17.13	6-6	16.45
5-3	15.61*	6-7	16.06*
5-4	14.09*	6-8	15.66*
5-5	12.58*	6-9	15.27*
5-6	11.06	6-10	14.88
5-7	8.5	6-11	19.53
5-8	13.44	6-12	20.16
5-9	16.89	6-13	18.94
5-10	18.65	6-14	19.78*
5-11	18.65*	6-15	20.62*
5-12	18.65*	6-16	21.46*
5-13	18.65	6-17	22.3
5-14	20.83	6-18	17.36
5-15	17.86	6-19	20.16
5-16	15.43	6-20	14.37
5-17	8.56	6-21	7.9
5-18	9.49*	6-22	9.09*
5-19	10.43*	6-23	10.28*
5-20	11.36	6-24	11.47*
5-21	12.14	6-25	12.66*
5-22	29.07	6-26	13.86*
5-23	18.12	6-27	15.06
5-24	20.18*	6-28	13.02
5-25	22.24*	6-29	14.16*
5-26	24.30*	6-30	15.30*
5-27	26.36*	7-1	16.45
5-28	28.41	7-2	16.45*
5-29	17.6	7-3	16.45
5-30	16.89	7-4	11.79
5-31	18.12	7-5	12.28*
6-1	20.58*	7-6	12.76*
6-2	23.05*	7-7	13.26*
6-3	25.51	7-8	13.74

*Interpolated Data Points

APPENDIX K

SUBJECT ONE - BIORHYTHMIC DATA

Birth Date: 2/10/38

Number of daysinto each cycle on indicated date.

Date	Physical	Emotional	Mental	Date	Physical	Emotional	Mental
4-30	4.0	13.0	29.0	6-4	16.0	20.0	31.0
5-1	5.0	14.0	30.0	6-5	17.0	21.0	32.0
5-2	6.0	15.0	31.0	6-6	18.0	22.0	33.0
5-3	7.0	16.0	32.0	6-7	19.0	23.0	1.0
5-4	8.0	17.0	33.0	6-8	20.0	24.0	2.0
5-5	9.0	18.0	1.0	6-9	21.0	25.0	3.0
5-6	10.0	19.0	2.0	6-10	22.0	26.0	4.0
5-7	11.0	20.0	3.0	6-11	23.0	27.0	5.0
5-8	12.0	21.0	4.0	6-12	1.0	28.0	6.0
5-9	13.0	22.0	5.0	6-13	2.0	1.0	7.0
5-10	14.0	23.0	6.0	6-14	3.0	2.0	8.0
5-11	15.0	24.0	7.0	6-15	4.0	3.0	9.0
5-12	16.0	25.0	8.0	6-16	5.0	4.0	10.0
5-13	17.0	16.0	9.0	6-17	6.0	5.0	11.0
5-14	18.0	27.0	10.0	6-18	7.0	6.0	12.0
5-15	19.0	28.0	11.0	6-19	8.0	7.0	13.0
5-16	20.0	1.0	12.0	6-20	9.0	8.0	14.0
5-17	21.0	2.0	13.0	6-21	10.0	9.0	15.0
5-18	22.0	3.0	14.0	6-22	11.0	10.0	16.0
5-19	23.0	4.0	15.0	6-23	12.0	11.0	17.0
5-20	1.0	5.0	16.0	6-24	13.0	12.0	18.0
5-21	2.0	6.0	17.0	6-25	14.0	13.0	19.0
5-22	3.0	7.0	18.0	6-26	15.0	14.0	20.0
5-23	4.0	8.0	19.0	6-27	16.0	15.0	21.0
5-24	5.0	9.0	20.0	6-28	17.0	16.0	22.0
5-25	6.0	10.0	21.0	6-29	18.0	17.0	23.0
5-26	7.0	11.0	22.0	6-30	19.0	18.0	24.0
5-27	8.0	12.0	23.0	7-1	20.0	19.0	25.0
5-28	9.0	13.0	24.0	7-2	21.0	20.0	26.0
5-29	10.0	14.0	25.0	7-3	22.0	21.0	27.0
5-30	11.0	15.0	26.0	7-4	23.0	22.0	28.0
5-31	12.0	16.0	27.0	7-5	1.0	23.0	29.0
6-1	13.0	17.0	28.0	7-6	2.0	24.0	30.0
6-2	14.0	18.0	29.0	7-7	3.0	25.0	31.0
6-3	15.0	19.0	30.0	7-8	4.0	26.0	32.0

APPENDIX L

SUBJECT TWO - BIORHYTHMIC DATA

Birth Date: 8/15/39 12 6 73
4 30/74

Number of days into each cycle on indicated date.

Date	Physical	Emotional	Mental	Date	Physical	Emotional	Mental
4-30	4.0	21.0	5.0	6-4	16.0	28.0	7.0
5-1	5.0	22.0	6.0	6-5	17.0	1.0	8.0
5-2	6.0	23.0	7.0	6-6	18.0	2.0	9.0
5-3	7.0	24.0	8.0	6-7	19.0	3.0	10.0
5-4	8.0	25.0	9.0	6-8	20.0	4.0	11.0
5-5	9.0	26.0	10.0	6-9	21.0	5.0	12.0
5-6	10.0	27.0	11.0	6-10	22.0	6.0	13.0
5-7	11.0	28.0	12.0	6-11	23.0	7.0	14.0
5-8	12.0	1.0	13.0	6-12	1.0	8.0	15.0
5-9	13.0	2.0	14.0	6-13	2.0	9.0	16.0
5-10	14.0	3.0	15.0	6-14	3.0	10.0	17.0
5-11	15.0	4.0	16.0	6-15	4.0	11.0	18.0
5-12	16.0	5.0	17.0	6-16	5.0	12.0	19.0
5-13	17.0	6.0	18.0	6-17	6.0	13.0	20.0
5-14	18.0	7.0	19.0	6-18	7.0	14.0	21.0
5-15	19.0	8.0	20.0	6-19	8.0	15.0	22.0
5-16	20.0	9.0	21.0	6-20	9.0	16.0	23.0
5-17	21.0	10.0	22.0	6-21	10.0	17.0	24.0
5-18	22.0	11.0	23.0	6-22	11.0	18.0	25.0
5-19	23.0	12.0	24.0	6-23	12.0	19.0	26.0
5-20	1.0	13.0	25.0	6-24	13.0	20.0	27.0
5-21	2.0	14.0	26.0	6-25	14.0	21.0	28.0
5-22	3.0	15.0	27.0	6-26	15.0	22.0	29.0
5-23	4.0	16.0	28.0	6-27	16.0	23.0	30.0
5-24	5.0	17.0	29.0	6-28	17.0	24.0	31.0
5-25	6.0	18.0	30.0	6-29	18.0	25.0	32.0
5-26	7.0	19.0	31.0	6-30	19.0	26.0	33.0
5-27	8.0	20.0	32.0	7-1	20.0	27.0	1.0
5-28	9.0	21.0	33.0	7-2	21.0	28.0	2.0
5-29	10.0	22.0	1.0	7-3	22.0	1.0	3.0
5-30	11.0	23.0	2.0	7-4	23.0	2.0	4.0
5-31	12.0	24.0	3.0	7-5	1.0	3.0	5.0
6-1	13.0	25.0	4.0	7-6	2.0	4.0	6.0
6-2	14.0	26.0	5.0	7-7	3.0	5.0	7.0
6-3	15.0	27.0	6.0	7-8	4.0	6.0	8.0

APPENDIX M

SUBJECT THREE - BIORHYTHMIC DATA

Birth Date: 11/13/44

4 30 74

Number of days into each cycle on indicated date.

Date	Physical	Emotional	Mental	Date	Physical	Emotional	Mental
4-30	20.0	9.0	3.0	6-4	9.0	16.0	5.0
5-1	21.0	10.0	4.0	6-5	10.0	17.0	6.0
5-2	22.0	11.0	5.0	6-6	11.0	18.0	7.0
5-3	23.0	12.0	6.0	6-7	12.0	19.0	8.0
5-4	1.0	13.0	7.0	6-8	13.0	20.0	9.0
5-5	2.0	14.0	8.0	6-9	14.0	21.0	10.0
5-6	3.0	15.0	9.0	6-10	15.0	22.0	11.0
5-7	4.0	16.0	10.0	6-11	16.0	23.0	12.0
5-8	5.0	17.0	11.0	6-12	17.0	24.0	13.0
5-9	6.0	18.0	12.0	6-13	18.0	25.0	14.0
5-10	7.0	19.0	13.0	6-14	19.0	26.0	15.0
5-11	8.0	20.0	14.0	6-15	20.0	27.0	16.0
5-12	9.0	21.0	15.0	6-16	21.0	28.0	17.0
5-13	10.0	22.0	16.0	6-17	22.0	1.0	18.0
5-14	11.0	23.0	17.0	6-18	23.0	2.0	19.0
5-15	12.0	24.0	18.0	6-19	1.0	3.0	20.0
5-16	13.0	25.0	19.0	6-20	2.0	4.0	21.0
5-17	14.0	26.0	20.0	6-21	3.0	5.0	22.0
5-18	15.0	27.0	21.0	6-22	4.0	6.0	23.0
5-19	16.0	28.0	22.0	6-23	5.0	7.0	24.0
5-20	17.0	1.0	23.0	6-24	6.0	8.0	25.0
5-21	18.0	2.0	24.0	6-25	7.0	9.0	26.0
5-22	19.0	3.0	25.0	6-26	8.0	10.0	27.0
5-23	20.0	4.0	26.0	6-27	9.0	11.0	28.0
5-24	21.0	5.0	27.0	6-28	10.0	12.0	29.0
5-25	22.0	6.0	28.0	6-29	11.0	13.0	30.0
5-26	23.0	7.0	29.0	6-30	12.0	14.0	31.0
5-27	1.0	8.0	30.0	7-1	13.0	15.0	32.0
5-28	2.0	9.0	31.0	7-2	14.0	16.0	33.0
5-29	3.0	10.0	32.0	7-3	15.0	17.0	1.0
5-30	4.0	11.0	33.0	7-4	16.0	18.0	2.0
5-31	5.0	12.0	1.0	7-5	17.0	19.0	3.0
6-1	6.0	13.0	2.0	7-6	18.0	20.0	4.0
6-2	7.0	14.0	3.0	7-7	19.0	21.0	5.0
6-3	8.0	15.0	4.0	7-8	20.0	22.0	6.0

APPENDIX N

```
FORTRAN IV C LEVEL  2C        FOURIA          DATE = 74211

      SUBROUTINE FOURIA(LP,  Y,M,AHC,SYS,A,B,E)
      DIMENSION Y(1),A(1),E(1),E(1)
      L=LP
      LM=L-1
      IL = 2
      N = L/2
      NFI=N=L
      IF(MCD(L,2).NE.0) IL=1
      ME=M
      IF(M.LE.0.CR.M.GT.N) ME=N
      SUMYS = 0.
      DO 13 I = 1,L
   13 SUMYS = SUMYS + Y(I) ** 2
      SYS = SUMYS
      C = 1.
      C = 2.
      S = 0.
      FL = L
      FN = FL/2.
      CCN1 = 6.283185/FL
      C1=CCS(CCN1)
      S1=SIN(CCN1)
      CCN2 = 2./FL
      IM = 1
      D) 28 J = 1,NP1
      IP = J - 1
      IF (J.EQ.NF1) IM-IM+IL
      U2 = 0.
      U1 = 0.
      LN = L
      DO 23 K = 1,LM1
      UO = Y(LN) + Q*U1 - U2
      U2 = U1
      U1 = U0
   23 LN = LN - 1
      AAA = CCN2 * (Y(1) + C* U1 - U2)
      IF(IF.GT.0) GO TO 251
      AHO = AAA/2.
      SUMC = AHC * AAA
      GO TO 26
  251 IF(IM.LT.3) GO TO 252
  253 A(N) = AAA/2.
      B(N) = 0.
      SUMC = SUMC + A(N)*AAA
      GO TO 254
  252 A(IF) = AAA
      B(IP) = CCN2 * S * U1
      SUMC = SUMC + A(IP) ** 2 + B(IP) ** 2
```

```
254 E(IP) = SUMYS - FN * SUMC
C
 26 IF(IP.EG.ME) GO TO 33
    G = C1 * C - S1 * S
    S = C1 * S + S1 * C
    C = G
    G = C+G
 28 CONTINUE
C
C
    33 RETURN
          END
```

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